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# On the relationship between the menstrual cycle and the body weight and food intake of women

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**Summary.** Body weight and food intake of women are analyzed over the whole menstrual cycle. Over 68—94 days body weight and food intake of eight women and three men are recorded. For food intake, a diary self-report method is used. The beginning of each woman's menstrual cycle is also recorded. Body weight and food intake are regarded as stochastic processes. The theory of time series and spectral analysis is applied. As opposed to the males, in the spectra of seven females, there is a peak at a frequency with the period of the respective females' menstrual cycles. There are no further consistent differences. This sine wave reaches its maximum two to three days before menses. The data suggest that, as a first approximation, the body weight of women during a complete menstrual cycle can be described by a simple sine wave. For food intake, the spectra show hardly any differences between females and males. However, it is shown that the same sine wave as in body weight is also contained in the food intake of seven females, reaching its maximum about four days before menses.

**Key words:** Body weight — Food intake — Menstrual cycle — Stochastic processes — Spectral analysis

## Die Beziehung zwischen Monatszyklus, Körpergewicht und Nahrungsaufnahme (Eßverhalten) bei Frauen

**Zusammenfassung.** Körpergewicht und Nahrungsaufnahme von Frauen werden über den gesamten Menstruationszyklus analysiert. Über 68—94 Tage werden Körpergewicht und Nahrungsaufnahme von acht Frauen und drei Männern registriert. Für die Registrierung der Nahrungsaufnahme wird eine Tagebuchmethode verwendet. Der Beginn eines jeden Menstruationszyklus der Frauen wird ebenfalls registriert. Körpergewicht und Nahrungsaufnahme werden als stochastische Prozesse behandelt. Es wird die Theorie der Zeitreihen- und Spektralanalyse angewandt. Im Gegensatz zu den Männern zeigt sich in den Spektren von sieben Frauen ein Gipfel bei einer Frequenz mit der Periode der jeweiligen Menstruationszyklen der Frauen. Es zeigen sich keine weiteren konsistenten Unterschiede. Diese Sinusschwingung erreicht ihr Maximum zwei bis drei Tage vor Beginn der Menses. Die Daten deuten darauf hin, daß das Körpergewicht von Frauen während eines gesamten Menstruationszyklus, als erste Annäherung, durch eine einfache Sinusschwingung beschreibbar ist. Bei der Nahrungsaufnahme zeigen sich in den Spektren kaum Unterschiede zwischen Frauen und Männern. Es wird jedoch gezeigt, daß dieselbe Sinusschwingung, wie beim Körpergewicht gefunden, auch in der Nahrungsaufnahme von sieben Frauen beinhaltet ist. Sie erreicht ihr Maximum etwa vier Tage vor der Menses.

**Schlüsselwörter:** Körpergewicht — Nahrungsaufnahme — Menstruationszyklus — Stochastische Prozesse — Spektralanalyse

## 1 Introduction

The data of a large number of human and animal studies suggest a relation between the menstrual cycle and the food intake and body weight of females. In many animal studies a cyclic pattern of food intake and body weight has been shown during the menstrual (or estrous) cycle. Concretely, food intake of rhesus monkeys (Czaja, 1975, Rosenblatt et al., 1980), gips (Friend, 1969), sheep (Forbes, 1971), rats (Tarttelin & Gorski, 1973) and guinea gips (Czaja & Goy, 1975) show relatively high values at menses, decreasing slowly until ovulation (or estrous) and subsequently increasing again until menses. The same cyclic pattern has also been found in the body weight of rats (Tarttelin & Gorski, 1973) and guinea gips (Czaja & Goy, 1975), while in gips (Friend, 1969) and baboons (Gilbert & Gillman, 1956) an increase in body weight has been found at ovulation.

In human studies, until now, there has not been an examination of the food intake and body weight of women over the whole menstrual cycle. Previous studies restricted their attention to a comparison of food intake and/or body weight of women at certain times or time intervals within the menstrual cycle. So, for example, there is a report of higher food intake in a ten-day-interval before menses in comparison to a ten-day-interval after menses (Dalvit, 1981). Slightly increased levels of food intake and body weight were found in the midpoint of the luteal phase as opposed to those in the midpoint of the follicular phase (Pliner & Fleming, 1983). Higher body weight at menses and a reduction at ovulation is reported, for several women (Golub et al., 1965). Note that in all these studies the selection of subjects was restricted to females only; there was no control of the results of the females by examining also the body weight and food intake of males.

With the restriction to certain times or time intervals within the menstrual cycle, no information about the different pattern of food intake and/or body weight for both sexes during the whole menstrual cycle can be extracted from these data. The longest period that can be analyzed is much shorter than the period of the menstrual cycle (for example in Dalvit, 1981) or is even shorter than the Nyquist period (for example in Pliner & Fleming, 1983) (for Nyquist period see f. e. Schwartz & Shaw, 1975, or Schlittgen & Streitberg, 1984). Thus, a period having the length of the menstrual cycle can't be analyzed at all (Jenkins & Watts, 1968). The data also do not allow any statistical control of further patterns like the — very often found — weekly patterns. These might have an influence on the respective results.

As a consequence it appears straightforward to analyze food intake and body weight throughout the *whole* menstrual cycle. By this way we get more insight into the dynamics of these variables, and we can hope to deduce at least some hypothesis about the behavior of body weight and food intake during a menstrual cycle. This is tried in the present study.

## 2 Method

### 2.1 Subjects

Eleven subjects of diverse professions took part in the study. Eight subjects were female, three male. The female subjects did not take oral contraceptives. They all reported quite regular menstrual cycles. The subjects were between the ages of 20 and 48 years, with a mean of 32.75 years for the females and 40.33 years for the males. The duration of the menstrual cycles of the females was between 23 and 33 days (mean = 28.00). The subjects participated in the study between 68 and 94 days (mean = 84.55) (Tab. 1). All subjects reported good health at the beginning of the participation. They were all normal weighted.

Tab. 1: Lengths of the subjects's time series and — in case of females — of the period of their menstrual cycles.

| Subjects | Time series | Menstrual Cycle |
|---|---|---|
| S1 | 94 | 33 |
| S2 | 90 | 31 |
| S3 | 88 | 29 |
| S4 | 86 | 28 |
| S5 | 84 | 28 |
| S6 | 78 | 26 |
| S7 | 78 | 26 |
| S8 | 68 | 23 |
| S9 | 92 | – |
| S10 | 88 | – |
| S11 | 84 | – |

### 2.2 Procedure

For an empirical examination of a patterned behavior of women in body weight and food intake during the menstrual cycle, time series of several subjects of both sexes are needed, both for daily body weight and for daily food intake. To obtain subjects I directly asked several persons to take part in a research project on the relationship between food intake respectively body weight and the menstrual cycle. I only asked persons, who were well known to me and who in my opinion would be very conscientious in both recording the daily food intake and measuring the daily body weight. The persons were told that they would have to record their daily food intake, that they would have to measure their body weight daily, and, for females, that they would have to record the beginning of their menses. They should keep do so for at least 60 days to get data for at least two complete menstrual cycles. They would receive no money for their participation.

The volunteering subjects were given a detailed five-page-paper with the rules for their participation. Especially, this paper contained a lot of examples how to record food intake. The subjects also received a small pocket-sized diary. They were instructed to record in as detailed a manner possible every item they ate or drank and the amount of this item. If possible the subjects' recordings should be quantitatively; that is, if known, the quantitative calorie intake and food intake's weight should be recorded. The subjects were further instructed to record how the food was prepared. From these records calorie and (food intake's) weight estimations were made using a standard reference (Souci & Bosch, 1982) by a coder who was blind with respect to which phase of the menstrual cycle the subject was in. For each subject, these respective estimations were summed up for each single day of participation. This data constitute the time series for caloric food intake and food intake's weight. The subjects were also asked to measure daily body weight. The measurements were done always at about the same hour. They were done before breakfast and without clothing. The scales were calibrated. Body weight was measured to the nearest tenth of a kg. The females also recorded the beginning of their menses.

Throughout the whole time of participation the subjects were contacted by the experimenter if any questions arose about the entries in the diaries. The diaries were regularly reviewed clarifying any ambiguities of missing data.

### 2.3 Statistical analyses

The method of spectral analysis and time series analysis is applied. The spectral analysis is based on regarding body weight and food intake as stochastic processes. A stochastic process is a sequence $(X_t)$ of random variables that are generally dependent. This sequence is a function of time assigning every time $t$ a random variable $X_t$ (Jenkins & Watts, 1968, Schlittgen & Streitberg, 1984). The concrete time series are regarded as realisations of the respective stochastic processes. By means of a spectral analysis of the time series the dynamic dependences of the processes are analyzed.

The method is based on an estimation of the spectrum of a process. The spectrum describes the general frequency composition of the time series. It constitutes a decomposition of the whole variance of a time series in contributions of the single frequencies. To reach this, first, the autocorrelation function of a time series is estimated. The autocorrelation function assigns to every time interval $\tau$ in the time series the correlation of the respective pairs of random variables $(X_t, X_{t+\tau})$. By this a description of the linear dependence of the values of the data at one time on the values at another time is achieved. Taking this function instead of the time series for the further estimation procedure guarantees a good control of the random fluctuations within the time series. The estimation of the spectrum is now completed by means of a Fourier-transformation of the estimated autocorrelation function. Because of the high bias due to this concrete estimation procedure (for example Schlittgen & Streitberg, 1984), in detail, a corrected method is used. The bias can be nearly eliminated by an appropriate multiplication of the autocorrelation function with a special set of scalars, leading also to a truncation of the autocorrelation function. Within the spectral domain this so-called window corresponds to a convolution of the Fourier-transformation of the autocorrelation function with an appropriate weighting function. Concretely, the Bartlett-Priestley-window is used with a truncation point of half the length of the time series (Schlittgen & Streitberg, 1984, p. 320). This estimation procedure results in an estimation with only small bias and also small variance. The spectrum is estimated for the Fourier-frequencies.

An alternative estimation procedure would consist in an ARMA-modeling of the time series within the time domain. This linear modeling then could be used for an estimation of the spectrum (Box & Jenkins, 1970). However, this kind of modeling we can do also after the above described estimation of the spectrum, because every ARMA-process results in a special spectrum. Furthermore, *a priori* there is no reason at all using linear ARMA-modeling. We could also make use of a nonlinear polynomial modeling of the spectrum. Here I am not engaged in the question of finding appropriate models for the respective time series. I guess this premature until more data are available. Box & Jenkins also propose the use of a difference filter (AR*I*MA) in case of a poor stationarity of the process. This filter is a high pass filter, so in the present case its application would result in an attenuation of the amplitudes of the lower frequencies. By this way possible higher amplitudes of frequencies of about the length of a menstrual cycle would be eliminated. I don't make use of it here.

The spectrum and the autocorrelation function of a process are directly related by the Fourier-theorem. They both contain the same information. So it plays no role at all whether the spectrum or the autocorrelation function are used for the analysis. However, there is still the possibility to compute a less noisy correlation function than the autocorrelation function (Bendat & Piersol, 1971, p. 31). Concretely, if the estimation of the spectrum (or of the autocorrelation function) suggests a concrete signal that might be related to the menstrual cycle, the computation of the cross-correlation function of the process with this signal provided a clearer extraction of the correlation function and makes the signal more visible. Thus, if we have a hypothesis about what the signal that is related to the menstrual cycle looks like, we can reach a better ratio signal/random in the correlation function by the estimation of the cross-correlation function between the time series and the signal. This function also gives information about the *phase* of the signal, so the signal can be exactly localized within the period of the menstrual cycle.

## 3 Results

### *3.1 Menstrual cycle and body weight*

A spectral analysis is computed for the Fourier-frequencies. Principally the problem could arise that the interesting frequency with the period of a woman's menstrual cycle just lies in the middle of two Fourier frequencies and so can't be analyzed directly. This problem does not arise here. The females' duration of participation was so harmonized with the females' periods of their menstrual cycles that the respective frequencies of these periods agree very well or are just identical with an analyzed Fourier frequency. Because the frequency dissolution for each subject depends on how long the subject's time series is, in the following I will give for every found peak's period the two neighbouring Fourier-periods. This gives a good impression for the local period dissolution and also facilitates orientation.

The spectra of the females' time series show two to five peaks (see also Fig. 1a). Concretely, the spectra of S1 and S4 show two peaks: S1 at (a period of) $p = 47.0$ (with the neighboured Fourier periods of $p = 94.0$ and $p = 31.333$) and at $p = 31.333$ (47.0, 23.5); S4 at $p = 86.0$ ($\infty$, 43.0) and at $p = 28.667$ (43.0, 21.5); there are no further peaks in the spectra of these subjects. The spectra of S2, S5, S6 and S7 show three peaks: S2 at $p = 22.5$ (30.0, 18.0), between $p = 15.0$ and $p = 12.86$ (18.0, 11.25), and at $p = 6.923$ (7.5, 6.429); S5 at $p = 42.0$ (84.0, 28.0), $p = 28.0$ (42.0, 21.0) and $p = 7.0$ (7.636, 6.462); S6 at $p = 26.0$ (39.0, 19.5), at $p = 19.5$ (26.0, 15.6) and between $p = 9.75$ and $p = 8.667$ (11.143, 7.8); S7 at $p = 39.0$ (78.0, 26.0), $p = 26.0$ (39.0, 19.5) and between $p = 6.0$ and $p = 4.875$ (6.5, 4.589). The spectrum of S8 shows four peaks: at $p = 22.667$ (34.0, 17.0), $p = 17.0$ (22.667, 13.6), between $p = 9.714$ and $p = 8.5$ (11.333, 7.556), and at $p = 6.8$ (7.556, 6.182). The spectrum of S3 shows five peaks: at $p = 29.383$ (44.0, 22.0), at $p = 22.0$ (29.383, 17.6), between $p = 17.6$ and $p = 14.667$ (22.0, 12.571), at $p = 11.0$ (12.571, 9.778) and $p = 5.5$ (5.867, 5.177).

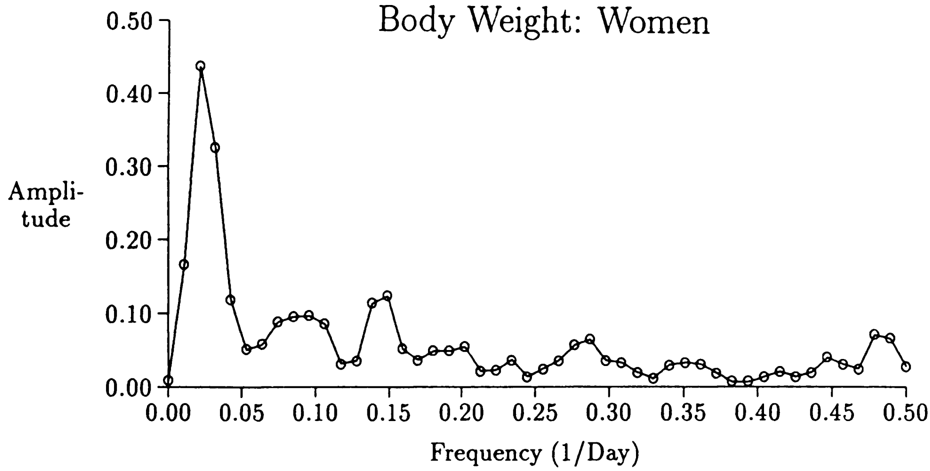


**Fig. 1a:** Spectrum of the body weight time series of one female (S1) (the period of this female's menstrual cycle is 33 days).

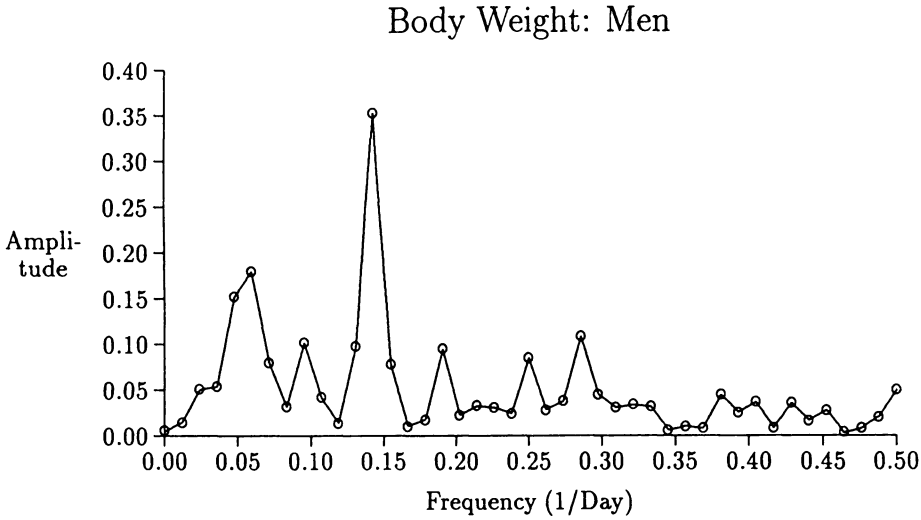


**Fig. 1b:** Spectrum of the body weight time series of one male (S11).

The periods of the peaks in the females' spectra are compared with the periods of the females' menstrual cycles. For seven females, the period of one peak agrees very well or is just identical with the respective period of the female's menstrual cycle (compare Tab. 1). For one female (S2), no respective peak can be found. For three females (S2, S5, S8), there are peaks that can be regarded as realisations of a weekly pattern: they belong to a sine with a period of about seven days. Furthermore, in the spectra of all females, there are one or two peaks, respectively, that appear difficult to interprete: periods of a length of 86 days (S4) or about 43 days (S1, S5, S7) or about 21 days (S2, S3, S6, S8) or about 16 days (S2, S3, S8) or about ten days (S3, S6, S8) or about five days (S3, S7).

The spectra of the males' time series show four to five peaks (see also Fig. 1b). Concretely, S9 shows peaks at $p = 92.0$ ($\infty$, 46.0), $p \doteq 46.0$ (92.0, 30.667), $p = 9.2$ (10.222, 8.364) and between $p = 5.111$ and $p = 4.381$ (5.412, 4.182); S10 at $p = 22.0$ (29.333, 17.6), $p = 12.571$ (14.667, 11.0), $p = 8.0$ (8.8, 7.333) and between $p = 5.87$ and $p = 5.5$ (6.289, 5.177); S11 at $p = 21.0$ (28.0, 16.8), $p = 16.8$ (21.0, 14.0) and $p = 7.0$ (7.637, 6.462). So, for one male, there is a peak at a period that can be regarded as a realisation of a weekly pattern, belonging to a sine with a period of seven days. In the spectra of all three males, there are some peaks at periods being difficult to interprete. These peaks' frequencies are very similar to some of those having already been found in the females' spectra: periods of a length of 92 days (S9), 46 days (S9) or about 21 days (S10, S11) or about 17 days (S11) or about twelve days (S10) or about four to five days (S9, S10). There are *no* peaks at periods of about the length of a menstrual cycle.

A comparison between the results of the females versus the males shows the following: the peaks at those periods that seem difficult to interprete ($p = 86$, $p = 43$, $p = 21$, $p = 16$ etc.) are met in the spectra of *both* some females *and* some males. None of these peaks can be found in the spectra of more than four females. Essentially the same is true for the peaks at a period suggesting a weekly pattern ($p = 7$): they also can be found in the spectra of both sexes, while neither all the males' spectra nor all the females' spectra exhibit that property. With respect to the peaks at periods of the length of a menstrual cycle the data do not show this feature. These peaks can't be detected in any male's spectrum, but only in the females' spectra. They also can be found for nearly *all* the females; S2 is the only exception. Note that, although the menstrual cycles' periods differ strongly individually (between 23 and 33 days; compare Tab. 1), the respective peaks' periods in the females' spectra are about identical to them.

### *3.2 Menstrual cycle and food intake*

For intake's weight, the spectra of the females' time series generally show a lot of and so only relatively slight peaks. For five females there can also be found some stronger peaks. Concretely, S2 shows a peak at (a period of) $p = 6.429$ (6.923, 6.0), S3 between $p = 11.0$ and $p = 9.778$ (12.571, 8.8), S4 at $p = 3.44$ (3.583, 3.308), S5 at $p = 3.652$ (3.818, 3.5) and $p = 2.8$ (2.9, 2.71), and S6 at $p = 9.75$ (11.143, 8.667). None of these periods appears easily interpretable. Instead the spectra do all look very similar to random processes. Strenghtening this impression neither the slight peaks' periods nor the stronger peaks' periods seem to be consistent over the subjects. There is also hardly any peak at a weekly period or at the period of a menstrual cycle. So a detailed analysis or an effort for interpretation generally appears little promising and is renounced here. Only the spectrum of S7 can be regarded as some exception of these regularities (Fig. 2a; compare also Discussion).

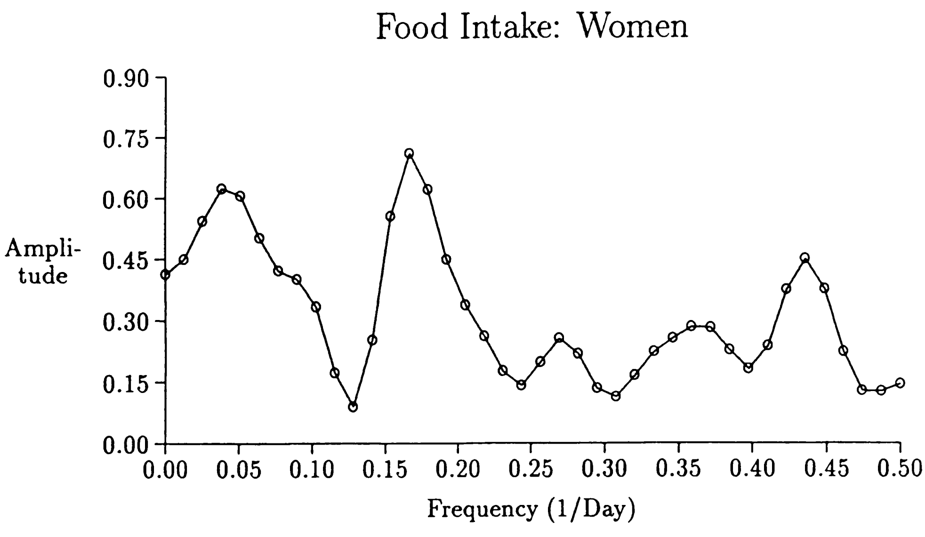


**Fig. 2a:** Spectrum of the time series for food intake's weight of one female (S7) (the period of this female's menstrual cycle is 26 days).

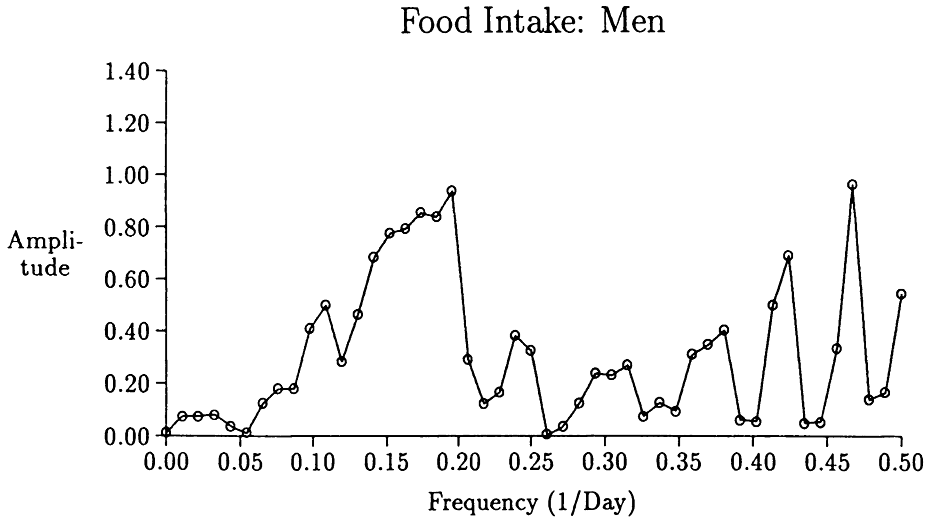


Fig. 2b: Spectrum of the time series for food intake's weight of one male (S9).

The spectra of the males' time series also show a lot of slight peaks. For one male (S11), there can also be found two stronger peaks at $p = 7.0$ (7.636, 6.462) and $p = 3.5$ (3.652, 3.36). The first of these two peaks' periods can be regarded as a realisation of a weekly period, while the status of the second is somewhat unclear. With respect to the slight peaks' frequencies there is hardly any consistency over the males. None of these peaks belongs to the period of a menstrual cycle. There is also hardly any peak at a weekly period. Like for the females, the peaks for two males look as if created by a random process. Only the spectrum of S9 can be regarded as some exception from this all (Fig. 2b; see also Discussion). So the results for both sexes generally look very similar.

For all subjects, the results for calorie intake are about the same as for the intake's weight; so they are renounced here (compare below).

## 4 Discussion

### *4.1 Body weight*

For body weight the results for women are clearly different from those of the men. The data suggest that a sine wave with the period of the length of a menstrual cycle constitutes the *main* difference between both sexes. The statistically found peaks at the weekly period and also some other periods like $p = 43$, $p = 21$ or $p = 17$ etc. should not be related to the menstrual cycle: they do not show regularly for all the females, and they are also present in some males' spectra. If they were related to the menstrual cycle this would imply that the concrete signal for some females would have to be drastically different from that of others; that is, for different females there could be a strongly different effect of the menstrual cycle on the body weight. However, this contradicts all known physiological correlates of the menstrual cycle.

Nevertheless, the question of how the peaks at those periods of $p = 43$ or $p = 21$ or $p = 17$ etc. could be explained arises. At first these peaks could result from an *aliasing* (Schlittgen & Streitberg, 1984). That is, these peaks could be artifacts, caused by a signal of a period lower than two days. Such a signal can't be detected when sampling on a daily basis. It is quite easy to show that they could really be reduced to about daily sine waves; however, note that such a sine wave can only cause an alias if the period is not exactly 1.0. On the other hand, these peaks could also be caused by estimation errors. Such estimation errors could result from the shortness of the time series. Finally a poor stationarity of the time series could be responsible due to the occurrence of some stronger random fluctuations within the realisations. Such random fluctuations can occur easily — for example, caused by illness, strong physical or also psychological efforts, weather conditions etc. — and by this way might induce, especially within shorter realisations, some artificial oscillations. An appropriate mathematical handling of such possible stationarity problems, however, is not quite easy within the present context (see Statistical Analyses).

**Tab. 2:** Results of the estimations of the cross-correlation functions between the body weight respectively food intake's weight time series and sine waves (see text). The highest values with the respective time lags in the functions are listed (C = correlation; L = time lag).

| Subjects | Body Weight | | Intake's Weight | |
|---|---|---|---|---|
| | Corr | Lag | Corr | Lag |
| S1 | .510 | 3 | .216 | 5 |
| S2 | .095 | 11 | .179 | 2 |
| S3 | .240 | 2 | .219 | 6 |
| S4 | .431 | 2 | .355 | 4 |
| S5 | .541 | 2 | .030 | 16 |
| S6 | .315 | 2 | .258 | 4 |
| S7 | .261 | 4 | .212 | 5 |
| S8 | .243 | 2 | .181 | 4 |

As a first approximation the above results suggest that the only signal that is related to the menstrual cycle is a sine wave with the period of a menstrual cycle. With this suggestion a less noisy correlation function is computed for the females' time series. The time series are cross-correlated with a sine wave that has a period of the length of the respective menstrual cycles, and that reaches its maximum value just at menses (see Statistical analyses). The computations are started at the beginning of the first menses in the time series. For seven females, the cross-correlation functions show clear sine waves of the respective periods of the females' menstrual cycles (Tab. 2, Fig. 3). They also indicate that the maximum is reached about two to three days before menses (mean = 2.43 Tab. 2). (Suppose, for example, the cross-correlation function reaches a maximum at lag 2. This means that the cross-correlated signal reaches its maximum two days later than the time series. However, the cross-correlated signal was set up to have its maximum just at menses. Consequently, the time series has its maximum just two days before menses). For S2 no respective sine wave can be found.

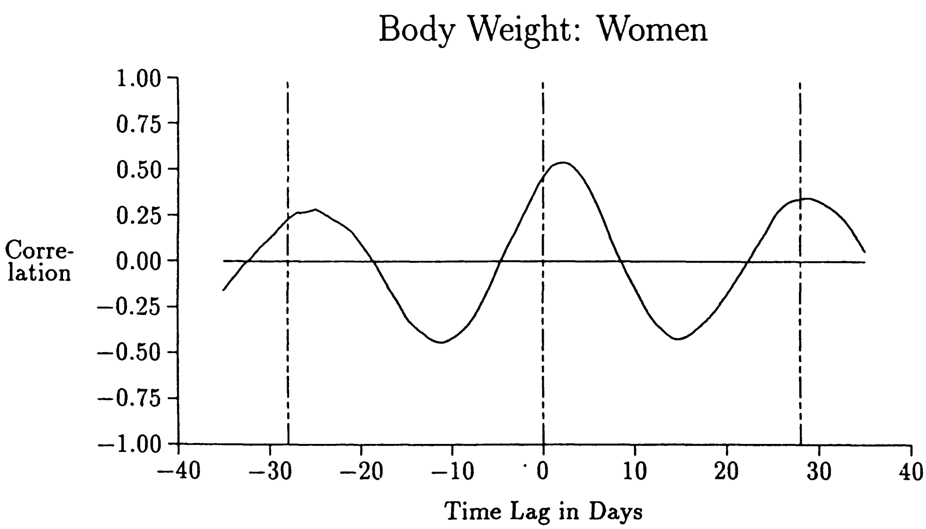


Fig. 3: Crosscorrelation function of the body weight time series of one female (S5) with a sine wave (the period of this female's menstrual cycle and of the sine wave are 28 days) (see text).

The hypothesis that the effect of the menstrual cycle on the body weight of women can be described by a simple sine wave with a maximum about two to three days before menses shows to be consistent with the results from previous human studies. With the phase information resulting from the estimations of the cross-correlation function it is predicted that the body weight of women is (a) higher in the midpoint of the luteal phase as opposed to the midpoint of the follicular phase, (b) higher before menses as opposed to after menses, and (c) higher at menses as opposed to ovulation. All these predictions have just been found empirically in previous human studies (Dalvit, 1981, Golub et al., 1965, Pliner & Fleming, 1983; see Introduction).

### 4.2 *Food intake*

For food intake the results for women show hardly any differences against that of the men. This data suggest that there is no effect of the menstrual cycle on the food intake of women. This result is in some way contrary to the results from previous human studies (see Introduction). These authors conclude that such an effect exists. On the other side, within none of these previous studies there is a comparison of food intake data between both sexes leaving behind some uncertainty with respect to this conclusion.

Nevertheless, the present result has to be regarded as surprising. First, the question raises whether it could be due to certain procedural characteristics within the present study. Indeed there are some differences in the procedure opposed to some previous studies. The subjects were not interviewed about their food intake. Instead the quantitative estimations of the food intake data were done from the subjects' own recordings (see Procedure). By this way the food intake data possibly are not estimated exactly enough. This could cause some measurement errors inducing an artificial randomization of the data. Second, about the same effect could be caused by the natural occurence of random fluctuations due to psychological or physical efforts. It would appear plausible that food intake is much more sensible for such random fluctuations than body weight. With respect to these possible causes for the randomness in the data, a comparison between the spectra of (the female) S7 and (the male) S9 is interesting (compare Fig. 2a and Fig. 2b). The spectra of both subjects do not look as randomized as those of all the other subjects (see Results). The period of the menstrual cycle of S7 is 26 days. The main difference between the two subjects consists of a broad peak at low frequencies about a period of 26 days that are only present in the spectrum of S7. (If you lay both spectra one upon the other you see that the rest of both spectra is quite similar for both subjects.)

It seems straightforward to test whether the signal that was hypothesized for body weight is also contained in food intake. The estimations of the cross-correlation functions in body weight showed that this sine wave reaches its maximum about two to three days before menses (see above). On daily eating behavior, a time delay of one to two days has been found between food intake and body weight (Bäuml, 1986, 1987). So, if the sine wave for food intake was also related to the menstrual cycle, it should reach its maximum about four days before menses (with the implicit assumption that, if there were a sine wave for both body weight and food intake, they should be directly related in phase). The estimations of the cross-correlation functions clearly demonstrate that such a sine wave exists (Tab. 2, Fig. 4). For seven females, the cross-correlation functions show sine waves of the respective periods of the females' menstrual cycles. S5 shows no respective sine wave. (The sine waves can be found both in intake's weight and in calorie intake; for six females, however, the sines prove to be a bit clearer for the intake's weight than for calorie intake. So the results for calorie intake are renounced here.) The functions indicate that the maximum of the food intake process is reached about four days before menses (mean = 4.29) and the minimum about four days before ovulation. So it can be concluded that the signal that was hypothesized for the females' body weight is also contained in the females' food intake.

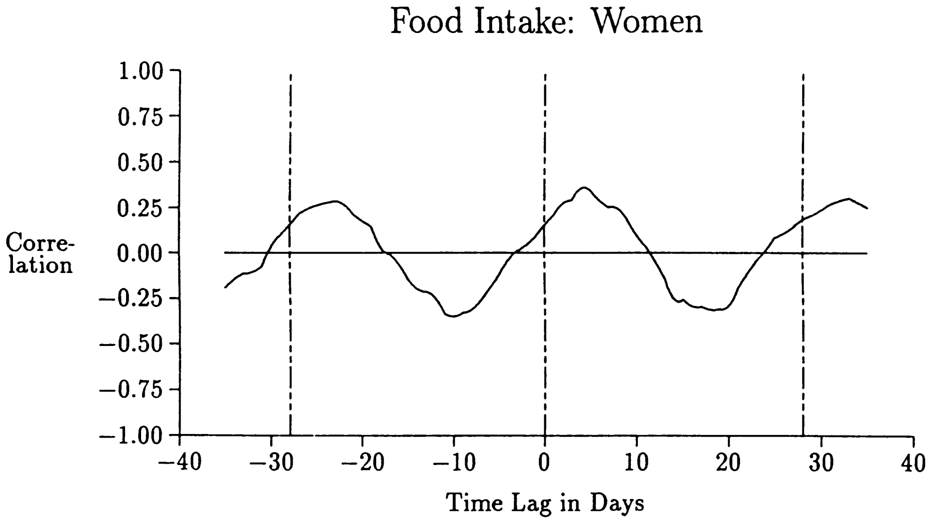


Fig. 4: Crosscorrelation function of the time series for food intake's weight of one female (S4) with a sine wave (the period of this female's menstrual cycle and of the sine wave are 28 days) (see text).

Finally note that the data from previous human studies are consistent with the assumption of a simple sine wave reaching its maximum about four days before menses: empirically, a higher food intake in a ten-day-interval before menses has been found in comparison to a ten-day-interval after menses, and also slightly increased levels of food intake in the midpoint of the luteal phase as opposed to those in the midpoint of the follicular phase were reported (Dalvit, 1981, Pliner & Fleming, 1983; see Introduction).

### *4.3 Conclusions*

The present data together with the data from previous studies suggest that, during a complete menstrual cycle, the effect of the menstrual cycle on women's body weight can be — at least approximately — described by a simple sine wave that reaches its maximum about two to three days before menses. Although this hypothesis seems at first to be too strong, no clear systematic deviations from data are obvious until now. For food intake, the situation is quite unclear. However, it is shown that the same sine wave as in body weight is also contained in women's food intake reaching its maximum about four days before menses. This is in accordance with data from previous studies.

Further studies should concentrate on time series as long as possible to reduce possible estimation errors. Possibly, the peaks at those frequencies that appear difficult to interprete then simply disappear. The studies should also be done with a lot of subjects — *both* females *and* males — to facilitate the identification of differences in the spectra. The present study clearly demonstrates the need not to restrict the subjects to females only.

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